No. 872,936. PATENTED DEC. 3, 1907.

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TUNGSTEN ELECTRIC INCANDESCENT LAMP.

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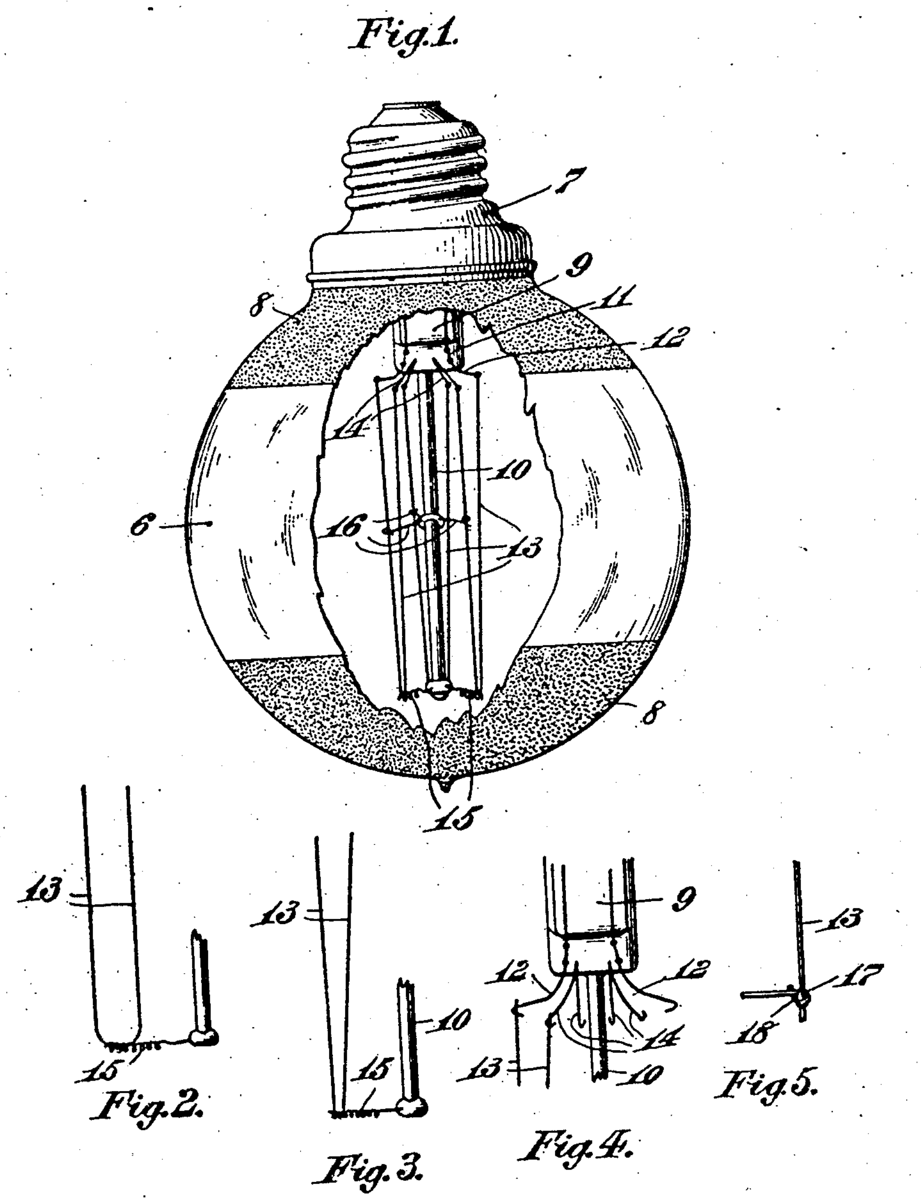

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TUNGSTEN ELECTRIC INCANDESCENT LAMP.

No. 872,936. Specification of Letters Patent. Patented Dec. 3, 1907.

Application filed January 19, 1905. Serial No. 241,782.

To all whom it may concern:

Be it known that I, JOHN ALLEN HEANY, a citizen of the United States, residing at York, in the county of York, State of Pennsylvania, have invented certain new and useful Improvements in Tungsten Electric Incandescent Lamps, of which the following is a full and clear description and which will enable those skilled in the art to fully understand the same.

In an application filed by me December 29, 1904, Serial No. 238769, I have disclosed the use of certain very refractory pure metals, metalloids, or mixtures of the same for filaments and electrodes together with certain new processes for manufacturing them. Such substances as tungsten, titanium, zirconium, molybdenum, osmium, silicon, and boron or mixtures of the same, are disclosed in this prior application. I have found that one of the most suitable substances therein named for use as an incandescent filament is, a very pure dense and homogeneous body of minute diameter (being almost hair-like) and consisting exclusively of metallic tungsten. This filament is placed in the bulb in which a vacuum is created. I have discovered that such a filament will stand a much higher temperature in such a vacuum than any carbon filament or a filament consisting of a carbid of tungsten for instance or carbids of similar refractory metals, or in fact than any other kind of a filament which has heretofore been known.

Before my invention it has not been possible to form a tungsten filament which had such a minute cross-sectional area and was of such sufficient length and strength so that it has been impossible to obtain the necessary resistance, because pure tungsten has a high specific conductivity. The reasons for these statements are well known in the art and require no extended discussion in the present specification.

My invention consists in forming a strong but very fine filament of tungsten either in the pure state or admixed with a small percentage of a suitable substance to increase the resistance without materially reducing the efficiency, and to mount such filaments in an electric lamp in such a manner that they can be used as practically and perfectly as the ordinary carbon filament.

I am aware that it is old to form a glower of a substance or substances having a second class conductivity, that is of substances which when cold are non-conductors, but which when heated become conductive. This forms no part of my present invention.

In the accompanying drawings I have shown a tungsten filament in an incandescent lamp and referring to said drawings, Figure 1 is an elevational view, partly in section, of said lamp, and Figs. 2, 3, 4, and 5 are enlarged detail views of the same.

To make a tungsten filament successfully, certain precautions are necessary as well as certain new and useful means are required to support such filament for use in the lamp.

My said application No. 238769 of December 29, 1904, discloses the process for making a tungsten filament which is much more efficient than the ordinary carbon filament, in almost exclusive use today, and in fact it discloses a process for making filaments which when mounted in a lamp is much more efficient than any incandescent electric lamp heretofore known; but the production of good tungsten filaments by such a process is necessarily slow and expensive. I, therefore, have devised a process by which said filaments can be made commercially in large quantities, and at a reduced cost and which will also be of superior quality and I have, also, devised certain new features relating more or less to the details of construction of the lamp and the means for supporting the filament in the lamp.

It will be readily understood that there is a great technical difference between successfully mounting a fragile tungsten filament, which is brittle, although elastic, when cold, and a tantalum filament, which is ductile and which can be permanently bent when cold. It is, therefore, impossible to wind a tungsten filament back and forth on a spider, as is done in the tantalum lamp. The tantalum lamp has a continuous filament supported by insulating supporting means, whereas my lamp has a plurality of individual filaments connected in series by conducting supports, which, however, are of such current carrying capacity that they remain practically cold.

In the process for making tungsten filament disclosed in my application No. 238769 the following steps are requisite: Tungsten which has been obtained in a fine powder and in a very high degree of purity is intimately mixed with a small percentage of paraffin and made into a plastic mass. It is then squirted through a small die under pressure into filamentary shape. The filament thus obtained may with due care be handled and is then placed in an oven, where its temperature is gradually raised to nearly the oxidation point of tungsten. During such heating the paraffin is driven out as vapor and is dissipated, as can be easily proven by an analysis of the filament, which will be found to be pure tungsten, or it can be easily proven by the fact that if the lump of paraffin which is to be used is placed on a glass, such as a watch glass, and is similarly heated it will vanish leaving no trace behind on the glass. The heating of the filament as above described apparently slightly frits the very fine tungsten particles together, and when cooled the filament can be mounted in an incandescent lamp in the same manner as is the ordinary carbon filament, but requires of course both care and skill since the breakage is considerable. After being so mounted and the bulb has been exhausted, a current of electricity either direct or alternating is sent through the filament and the filament shrinks greatly both in cross section and in length, owing to the fact that the particles become sintered into a dense mass and it is necessary to hang a small inert weight in the loop of the filament to give it the proper shape, the weight being afterwards removed. The most serious defect, however, is that the shrinkage is uneven, and two filaments may differ as to length and specific resistance, if the small particles of the powder squirted into the filaments is of varying degrees of fineness. Now, as my tungsten filaments become more or less plastic, when operated at say one watt or less per C. P. it has been found necessary to provide supporting means within the bulb for the filaments in order that the lamp can be burned in any position without danger of short circuiting.

Since only dense and homogeneous pure tungsten filaments can be worked at high efficiencies and since such filaments have a high specific conductivity I have found it necessary, not only to mount a plurality of such filaments (shaped like a hair-pin) in series within the bulb, but also to make the filaments of extremely small cross-section in order that the lamp containing these tungsten filaments may be operated upon ordinary commercial voltages as for example, 110 volts.

The filaments must be squirted through a die of very hard material, such for instance as the diamond or sapphire or similar material, in order that the material of the die will not be abraded and cause contamination, and because it is extremely difficult to bore the proper opening in a die of such hard material, it is almost impossible to form a very fine filament in this manner, the very finest opening which can be bored at the present time being too large for my purpose. I, therefore, have employed suitable tungsten compounds, which can be readily squirted through the rather small openings of the dies above referred to, and thereafter such a compound filament is reduced to metallic tungsten in such a way that the reduced metallic particles will adhere and the filament will shrink greatly both in length and cross-section. When it is afterwards sintered in the bulb by the electric current, the filament will shrink still further but under certain conditions this further shrinkage is but slight and the result will be a uniform filament of hair-like cross-section, readily retaining its shape in usage.

If the filament has uneven or weak spots, it may be flashed in vapor of tungsten oxychlorid and hydrogen whereby the hydrogen reduces the chlorin compound and metallic tungsten is deposited upon the weak spots or places in a manner analogous to the manner in which ordinary carbon filaments are flashed, in a hydro-carbon. But I find that it is not necessary to resort to this operation as it is very tedious and since the deposit of tungsten seems to be of a different physical nature or texture and scatters and discolors the bulb during use. It is cheaper to throw away defective filaments although the number of such defective filaments is reduced to a minimum by my new processes.

I have since substituted for the paraffin binder various low melting alloys which can be procured commercially and I mix the very fine pure tungsten powder with such an alloy when the low melting alloy is melted and have squirted such a mixture when in a warm mass into a wire, somewhat resembling ordinary fuse wire. The wire when cold is bent into the form required and on being heated by the passage of electric current through the wire in a vacuum, the alloy metal is boiled out and the tungsten particles readily sintered together shrinking greatly during the operation. I have found in such instances that it is impossible to drive out the last trace of such an alloy binder, and the filament so produced frequently blackens the bulb, when used. I have used camphor, starch, sugar and sulfur as a binder, adding a theoretical amount of tungsten oxid so that carbon from the carbonized binder would reduce such oxid, but carbon has such a particular affinity for tungsten even at a low temperature, say red heat, that I have found it necessary to keep such impurities out of the mass from the start, so that they need not be thereafter removed, and so that no trace of the same was left behind during removal such a trace being sufficient to ruin or greatly impair the final product.

I have obtained excellent results by the use of yellow tungsten oxid with a water or paraffin binder, and I have also used the blue and brown oxid and the sulfid similarly, each being reduced at a low heat in hydrogen. Tungsten oxids, if heated in ammonia, form nitrids, which can be easily decomposed to pure tungsten, the ammonia assists the heat in removing the paraffin binder before the oxid is hot enough to form the nitrid.

It is well known that the United States Patent to de Lodyguine No. 575002 of January 12, 1897, discloses the process for coating a fine carbon or platinum filament with tungsten by heating the filament by an electric current in the presence of hydrogen and the volatile chlorin compound of tungsten. I have observed that the deposit thus formed is partly oxid of tungsten, and that the carbon combines with the tungsten in any event to form the carbid by such a process, even if carried out under different degrees of pressure and temperature. The deposit is also of such a physical nature and texture that it will fly off and discolor the bulb if it is attempted to use the lamp. Where a platinum fillet is used the platinum alloys with the tungsten and forms a compound, which is readily fusible at a comparatively low temperature. It is, therefore, obvious that in my early attempts to manufacture filament in which a carbonizable binder was used with the fine tungsten powder, that the result would be much more suitable for use as a fillet upon which to deposit tungsten than the carbon fillet of de Lodyguine, since the final result or product would not contain nearly so much carbon even traces of which such as I have discovered are deposited from the small amount of vaporized hydro-carbon from the oil in the mechanical exhaust pump, are often suficient to form a low carbid when the pure tungsten filament is being worked free from occluded gases when highly heated during exhaustion. Such a carbid invariably blackens the bulb. I have tested such a deposit and have found it to be tungsten carbid and not tungsten or carbon alone, and this shows the necessity for keeping the carbon out entirely from the start to the finish of the process. I have tried to decarbonize such tungsten carbid filaments by methods used analogously with other carbid and have found that a little carbon invariably remains and this little is sufficient to greatly lower the efficiency of the lamp. All such methods were discarded for that method in which the fine tungsten powder was made into a paste with a paraffin binder since they were unreliable and too complicated. As hereinbefore stated the metal paste method does not produce a filament of sufficiently small cross-section although it is pure and the filament is much smaller than that resulting from the impure method of depositing tungsten upon a carbon core or core containing carbon.

I have discovered that the ammonium and amin tungstates can be made into a mass which can be squirted by merely mixing the same with a little water without the aid of any other binding means whatever and that such a squirted thread can be readily handled and wound upon forms, braided, coiled, &c., or such a mass may be formed into minute hollow tubes or sheets and in each case can be readily reduced in hydrogen by gently heating and that if, after the reduction is complete, the temperature is raised the metal particles frit into a dense, pure tungsten body which will shrink only very slightly or not at all even up to its melting point. This fact I deem of particular importance as it does away with the subsequent costly sintering operation and furthermore the unreduced threads can be looped and supported upon an inert rod, such as a tungsten rod or a magnesia or alumina rod coated with tungsten, while the free ends are hanging vertically in a vertical reduction furnace and that the metal filaments greatly shrink both in cross-section (a very valuable feature) and in length, although they remain strong and coherent and do not kink or tangle with each other and may be readily separated and mounted directly upon the final support in the bulb. Furthermore, a very small percentage of thorium added to the tungstate will cause it to shrink and sinter more readily. A little metallic zinc, aluminium or magnesium may be added to aid in reduction, these metals combining with the oxygen of the tungstates to form their oxids which may be volatilized out in the case of zinc oxid, or may remain within to increase the resistance, as in case of aluminium and magnesium oxids. On the other hand I may add a very little boron or silicon to increase the resistance without lowering the melting point very much, but the amount added should not be enough to form the well known borids or silicids, all of which are of low fusing points. In case a little silicon is added to the tungsten I have discovered that the carbon from the pump will form the carbid of silicon which is very refractory and of very high resistance and will thus prevent the formation of the undesirable tungsten carbid, although in some cases a little free silicon may be left over. In case a little rare earth oxid is mixed with the tungsten oxid or tungstates and formed and reduced in hydrogen, the tungsten compound only will be reduced and the remaining rare earth oxids which should be the most refractory ones known will thus increase the resistance. The reduction should take place in abundance or reducing gas, such as hydrogen or carbon monoxid or water gas and the gas can be afterwards passed through drying bottles, and used again especially as hydrogen is rather expensive.

In order to prepare my squirtable mass of tungstate and water I may start with a commercial tungstic oxid (WO_3) which is more or less pure, but I prefer to start with the minerals wolframite or scheelite. The former is fused with sodium carbonate and reduced to a sodium tungstate which is treated with a strong mineral acid to form tungstic oxid (WO_3) which is a yellow powder. If the ore scheelite is used it may be treated direct with a mineral acid to produce the tungstic oxid. The tungstic oxid is mixed with pure water and heated and stirred while ammonia gas is conducted into the liquid. When no more tungstic acid will dissolve the solution is filtered until clear. This solution is evaporated on water bath until one half remains and allowed to cool. By this time crystals will be formed around the edge of the dish which should be washed quickly with pure ice water, the liquid is to be thrown away as it contains most of the impurities. The salt thus produced is now oxidized in hot dilute nitric acid to which a little hydrochloric acid is added from time to time until the material has become rich orange in color and granular when it is allowed to settle and the acid and water poured off. The tungstic acid is now washed with pure distilled water and allowed to resettle and rewashed until the water which is poured off will not turn blue litmus paper red. The tungstic acid is dried on a water bath and weighed. This crystallization and oxidation is repeated five times but of course the last time the process is not carried beyond "crystallization" if the paratungstate is to be the final product in which case the crystals are not dried on the water bath but merely drained and air-dried. The tungstic oxid or para tungstate prepared in this manner are exceptionally pure and suitable for further manipulation into tungsten filaments. The tungstate is now ground up with a little water and can be easily squirted as above described and looped over a tungsten rod, the lower ends of the loop being cut with a pair of scissors so that a large number of hair pin shaped threads hang vertically, and are thus air-dried for a few hours. They are then placed in a vertical magnesia or alumina tube the inside of which is carefully lined with metallic tungsten and external heat applied by a powerful gas or electric heating means while the reducing gas, preferably hydrogen, is passed through. The heat is low at first until complete reduction takes place, after which it is increased so as to sinter the metallic filaments as much as possible. The reducing gas may be shut off and the reduction tube exhausted thereafter by means of a suitable pump, if desired, and may then be highly heated when upon cooling the filaments will be found dense and strong. They will hang in substantially straight loops and will resemble polished platinum, under the microscope. They will not stick to one another, under this treatment although they have been rendered very dense, and they are uniform as to shape, size and conductivity. This feature I deem of particular importance, in the commercial production of a tungsten lamp. The mounting of these filaments in the incandescent lamp introduces new features and precautions which are not met with in the ordinary carbon lamps. Tungsten filaments for example, when operating at one watt per C. P. or less, are somewhat plastic and unless supported will sag and bend out of shape, especially if the lamp is subject to vibration. Again when the lamp is not in use, and when the tungsten filament is consequently cold, it is rather fragile as it is of such small cross-section and very brittle. Furthermore the filaments often shrink slightly after being mounted upon the final support and means must be provided which will allow this shrinking without subjecting the filaments to undue strain and which will support the filament in the desired position without short circuiting. Such support should be able to absorb the shocks or vibration of the filaments during shipment.

I have shown in Fig. 1 a round bulb 6, although of course any shape of bulb desired may be used, and provided with a suitable socket or base 7, and either one or both of the ends of the bulb may be frosted if desired as shown at 8 to better distribute the light since the filaments are preferably disposed close to and parallel with the vertical axis of the lamp. The stem 9 has a glass or other support, 10 affixed thereto, and has sealed therein short lengths of platinum wire 11, one end of which is welded to the copper leads and the other is welded to a short length of iron, nickel or copper wire 12. The latter may be platinum if desired, but I prefer to use copper preferably nickel-plated. I have shown three tungsten filaments 13 of preferably hair-pin shape, but a greater or smaller number may be employed depending upon the length and diameter of the filament, and the voltage upon which the lamp is to be operated. The filaments are connected in series by means of short lengths of V-shaped wire 14, the apex of each being embedded in the glass stem 9, and these wires may be made of the same material as the wires 12, but are of sufficiently large diameter to remain practically cold during the passage of the electric current therethrough.

At the lower end of the support 10 are arranged a plurality of resilient arms 15, which may consist of fine spiral springs of suitable metal, such as platinum, iron, nickel, copper, tantalum or even carbon, and these springs are of such good heat conductivity that they remain cool during the operation of the lamp. They may be of sufficient diameter to remain thus cool and may be weakened by being flattened near the end where they are fused into the glass support 10, or they may be of very fine wire with a bead of tungsten or other good heat conducting material applied at the spot where the filaments and springs contact.

I have shown a series of intermediate supports 16 which may encircle one or both legs of each hair-pin filament loosely to prevent vibration, and these supports may be made of metal wire or of a metallic oxid, preferably covered with tungsten, or they may consist entirely of tungsten, as it is not necessary for them to bend during the operation of the lamp.

The mounting of the hair-pin filament upon the stem is as follows: The tungsten filaments as they come from the reduction tube are very dense, due to the high heating during the latter part of this operation, but the legs are substantially parallel as shown in Fig. 2. Each filament is slipped through the loose intermediate support 16, if such a support be employed and the free ends are engaged by the short connecting wires which have been previously bent into a small hook at their ends as shown in Fig. 4. This small hook can now be fused into an inclosing bead by suitable electrodes in hydrogen or other inert gas, but I prefer to form the short wire into a small eye, as shown in Fig. 5, and to pass the end of the filament therein loosely and to apply a paste of very fine tungsten, which can be readily prepared by reducing ammonium tungstate in hydrogen, and a little water, the paste being shown at 17 Fig. 5. Or a carbonizable binder may be added to the fine tungsten in which case the carbid may be formed but as this joint is not subjected to a very high heat, this is not a drawback. In any case, however, a loop of each hair-pin filament is in engagement with one of the convolutions of the spiral spring 15 preferably near the free end thereof as shown in Fig. 2. A little paste may be added where the spring and filament touch to prevent overheating if desired, and the stem is placed in a warm oven to dry the paste shown at 17. The water will be driven out and the eye 18 is then squeezed with a pair of red hot pincers which causes the eye to sink into the paste which is rendered semi-plastic by the heat and upon cooling a firm dense joint is formed which will not contaminate the filament and which will be cool when the lamp is in operation. The filament is not oxidized by this treatment even when it is carried on in the open air, such a manner of making the connection above described is in my opinion of great industrial importance. The lamp is now placed on the pump, the legs of each hair-pin filament being substantially parallel as shown in Fig. 2 and it is to be noted that the filaments are just as they come from the reduction tube and have not been subjected to a subsequent shrinking operation in a vacuum or inert environment, which has heretofore proved to be both expensive and tedious.

When the lamp is exhausted the current is sent through the series of filaments and each one shrinks slightly so that the legs thereof slightly converge toward the loop thereof as shown in Fig. 3 before the spring is put under perceptible tension. Each filament can thus shrink independently according exactly to the necessary or requisite amount and after it has been so shrunk to approximately its final position as shown in Fig. 3, it is supported in this desired position and can still expand or contract slightly by reason of the resiliency of the spring without subjecting the filament to a dangerous strain. In fact the spring will often take a permanent bend if the filament contracts strongly due to imperfect shrinkage in the reduction tube, but after such a permanent bend the spring will go on acting as before, namely, to keep the filament in the desired position and permit slight expansion and contraction of the filament during use. In addition the springs absorb shocks which might be otherwise dangerous to the brittle filament when it is cold, as for instance in shipment.

In my Patent No. 839585 of December 25, 1906, which is a division of my application No. 239769 filed December 29, 1904, I have disclosed and claimed the use of a filament formed from the alloy of tungsten and another refractory metal, together with the process for making it, and in my Patent No. 842546 of January 29, 1907, which is also a division of said application No. 238769 I have disclosed and claimed a pure titanium filament and the process of making it. In another divisional application No. 344068 filed November 19, 1906, I have claimed a new process for making refractory metallic filaments, and in another divisional application No. 332786 filed August 31, 1906, I have claimed a tungsten filament, having certain new characteristics, and which last named application is now involved in an interference. In the original Case No. 238769 I have retained certain claims to novel processes for making refractory metallic filaments of high efficiency.

The certain novel features of the incandescent filaments and the process of making the same and also certain novel features for mounting and connecting them to the lead-in wires as set forth in the present application have been claimed in divisional applications, filed April 18, 1906, Serial Nos. 312392; 312393, and 312394.

Having thus described the nature and object of my invention what I desire to claim and secure by Letters Patent:

1. The combination of a plurality of fine hair-pin shaped filaments of dense but fragile refractory metallic material connected in series and a support for said filaments within a vacuum bulb with suitable current connecting wires for said series of filaments, said support comprising a plurality of spiral springs, each of which engages a filament at the loop thereof, and an additional steadying means located between said springs and the other end of each filament.

2. A high voltage incandescent electric lamp comprising filaments formed into a coherent mass and consisting mostly of tungsten mounted in a plurality of hair-pin shaped units in series and supported by a fine spiral spring at the loops of each hair-pin and by suitable connections at the other end and having also an additional steadying means.

3. A mount for refractory metallic filaments comprising a stem with suitable lead-in wires and a support mounted upon said stem and comprising a plurality of short conductors to connect a plurality of fine hair-pin filaments in series at one end thereof, a plurality of fine resilient spiral supports at the other end thereof to engage each hair-pin filament and additional intermediate steadying means for the filaments.

4. The method of mounting refractory metallic filaments which are dense, but which are subject to slight longitudinal contraction after being mounted on the support in the bulb and during use of the lamp, which comprises the connecting of a plurality of fine hair-pin filaments in series by the aid of intermediate short conductors of greater current carrying capacity and in connecting both terminals of the series of filaments with suitable lead-in wires, the short conductors and lead-in wires acting as supports for the end of the hair-pin filaments opposite the loops thereof, and in providing a plurality of resilient supports which are insulated from each other and one of which engages each hair-pin filament at the loop thereof, and then heating said filaments so as to contract each slightly thereby causing the straight lengths thereof to converge slightly towards the loops thereof and thereby simultaneously causing each resilient support to be placed under slight and individual tension as the individual shrinkage of each filament requires.

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